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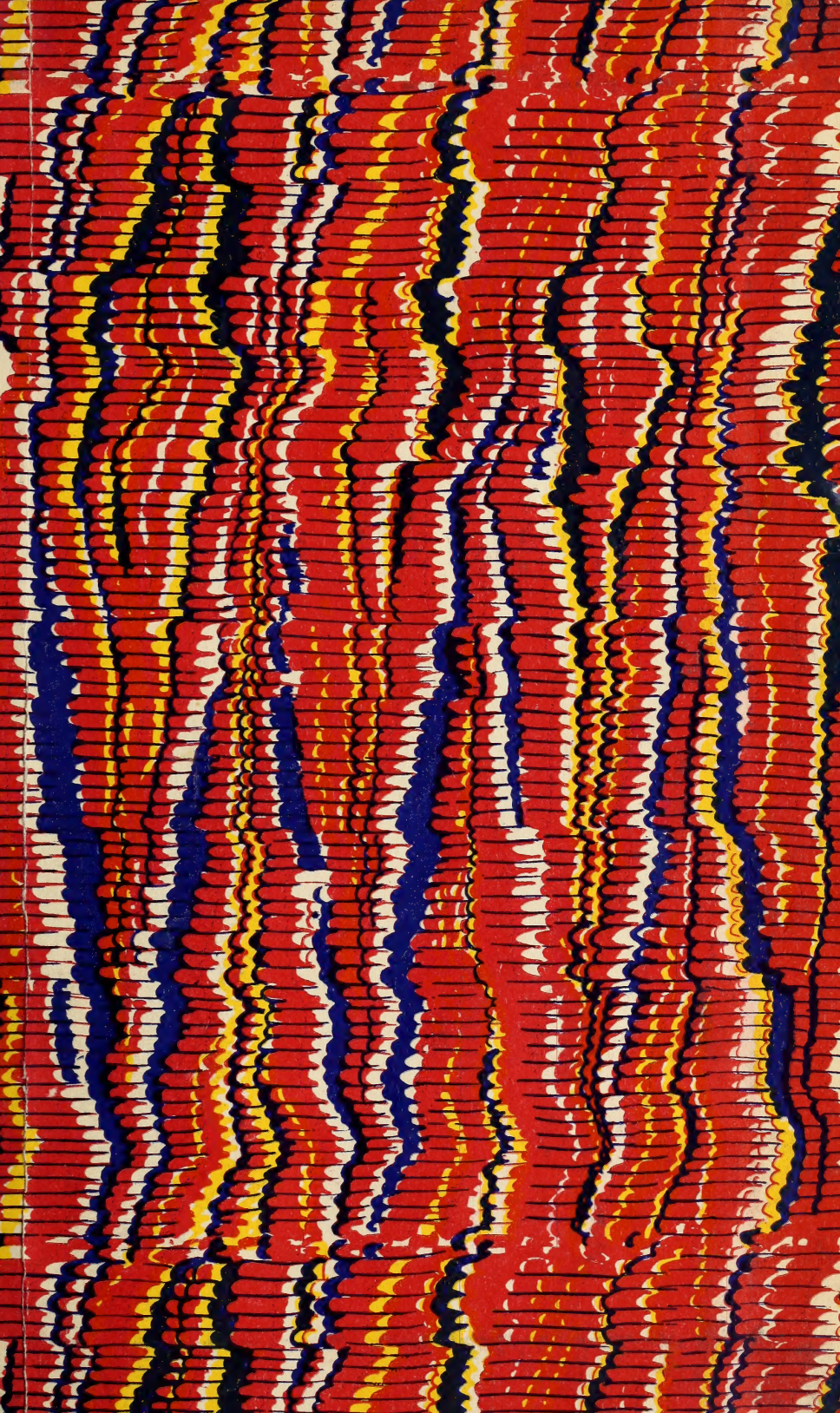

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THE RECOVERY OF POTASH AS A BY-PRODUCT IN THE BLAST-FURNACE INDUSTRY.

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CONTENTS.

	Page.
Introduction	1
Recovery of potash in the cement industry	2
Method of investigating loss of potash in the blast-furnace industry	2
Reactions within the blast furnace	3
Classification and sources of iron ores	4
Blast-furnace fluxes	5
Blast-furnace fuels	5
Factors governing volatilization of potash in blast furnaces	6
Potash in blast-furnace raw materials and slags	8
Estimated loss of potash in the blast-furnace industry	15
Possibility of potash recovery	16
Summary	18
Bibliography	19

INTRODUCTION.

When a potash silicate is mixed with lime and ignited at a temperature above 1,000° C. more or less of the potash is set free, depending on the temperature and the proportion of lime used. It was observed by Ross[2] that when one part of feldspar was ignited with three parts of calcium carbonate complete volatilization of the potash occurred at a temperature of 1,300° to 1,400° C. This suggested a possible procedure for the commercial production of potash from silicate rocks, and attempts have been made on a commercial scale for the direct recovery of potash in this way. It unfortunately happens, however, that the percentage of potash in all commercial grades of insoluble silicates is comparatively low, and no process for recovering potash from such materials can offer much promise of profitable application unless there is also produced some product of value in addition to the potash.

[1] Acknowledgment is made to R. M. Jones, William Hazen, T. R. LeCompte, W. B. Pope, and G. J. Hough, of the Bureau of Soils, for assistance in the analytical work.

[2] Ross, William H. The extraction of Potash from Silicate Rocks. Circular No. 71, Bureau of Soils, pp. 1-10. Original Communications, Eighth International Congress of Applied Chemistry, v. 15, pp. 217-229. 1912.

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The two manufacturing industries of this country which have the largest outputs are the Portland-cement and blast-furnace industries. The raw materials used in both these industries contain small amounts of potash silicates, and in the process of manufacture these materials are ignited with lime at such temperatures that more or less of the potash is set free and escapes by volatilization. These two industries are already firmly established, and for them the problem becomes merely one of the successful recovery of the volatilized potash as a by-product.

RECOVERY OF POTASH IN THE CEMENT INDUSTRY.

A survey has been made by Ross, Merz, and Wagner[3] of the potash that escapes from the cement plants of the country. Representative samples of raw mix and of the corresponding ground clinker were collected from all but four of the cement plants then operating and their potash contents determined. With a knowledge of the ratio of raw mix consumed to ground clinker produced it was possible to make a close estimate of the potash lost from each individual plant. The results obtained varied from 0.35 to 5.14 pounds of potash per barrel of cement produced, with an average for all plants of almost 2 pounds. On the basis of an average production of 90,000,000 barrels, the total potash escaping from all the cement plants of this country was estimated to amount to about 87,000 tons annually. Since these estimates were made, installations have been placed in a number of plants for the recovery of this potash, and in every case the quantity that was found to escape from the kilns closely agreed with the estimates that had been made during the course of the survey. It is therefore logical to assume the reasonable correctness of the total estimate that was made for all the plants of the country.

During the war active steps were taken at a number of plants to recover the potash that escapes from the kilns, and the cement industry then became an important source of potash in this country.

METHOD OF INVESTIGATING LOSS OF POTASH IN THE BLAST-FURNACE INDUSTRY.

When the survey of the cement industry was completed a corresponding study was undertaken of the potash that escapes from the blast furnaces of the country. It was originally planned to conduct this investigation along lines exactly analogous to those employed for the cement industry by obtaining samples of the materials fed into the individual furnaces and of the corresponding slags, determining the potash in these samples, and then calculating the loss of potash per ton of pig iron produced at any given furnace from known ratios of ore, flux, coke, and slag to pig iron. It was soon realized, however, that this procedure would not be practicable in the case of the blast-furnace industry, owing to essential differences of operation in these two industries. For the production of cement each individual plant is located at or near sources of its raw materials, which are so combined that the composition of the finely ground raw mix is fairly constant.[4]

[3] Ross, William H., Merz, Albert R., and Wagner, C. R. The Recovery of Potash as a By-Product in the Cement Industry. Bul. 572. U. S. Dept. Agr., pp. 1–22. 1917.

[4] Idem.

It is thus possible to determine the potash content of the charge used in a cement plant from the analysis of a single representative sample.

The burdens of blast furnaces, on the other hand, may change from time to time and often consist of different ores from widely separated sources, of limestone and dolomite obtained from various localities, and of cokes derived from different coal beds. The potash content of these several constituents may vary considerably and changes in the relative proportions of the constituents of the charge will cause corresponding variations in the potash content of the burden. The raw materials, moreover, are not uniformly mixed and ground before being charged into the furnace, and it is therefore not practicable to collect a single sample which would be representative of the charge as in the case of the cement industry. It is also possible in the latter industry to get fairly reliable data on the ratio of raw mix to ground clinker, but the weight of the blast-furnace charge to the slag obtained is subject to change and reliable data on the ratio of slag produced per ton of pig iron could not always be obtained.

It was decided, therefore, to attack the problem by obtaining from their principal sources representative samples of the raw materials, iron ores, fuels, and fluxes, that are consumed in the blast-furnace industry. Knowing the annual consumption of these materials in this industry and their average potash content as determined by analysis it should be possible to calculate approximately the total amount of potash that is annually charged into the blast furnaces of the country. The potash in the slag varies in different furnaces and in the same furnace from time to time. By analyzing a large number of samples an average value can be obtained for their potash content. This value multiplied by the yearly output of slag and deducted from the total potash charged in the furnaces of the country will give the amount of potash that is annually lost by volatilization in this industry.

REACTIONS WITHIN THE BLAST FURNACE.

The blast furnace, in which the manufacture of pig iron is conducted, is a cylindrical steel shell which varies in height from 40 to 100 feet or more. The diameter of the shell varies from top to bottom with the outlines adjusted for the various changes occurring in it. The walls of the hearth near the bottom of the furnace are pierced with openings through which a strong blast of heated air is forced to unite with the carbon of the fuel. The entire shell is lined with fire brick.

Into the top of the furnace are charged continuously the ores, flux, and fuel which constitute the burden. The ore supplies the iron for which the furnace is operated, the fuel in combustion yields gases that reduce the iron to a metallic state and supplies the heat required for the reactions occurring within the furnace and for the fusion of the resultant iron and slag. The flux unites with various compounds which would otherwise be infusible at the temperature prevailing in the furnace and thus removes in a liquid state as slag the ash of the fuel as well as the earthy impurities occurring in the ore. The molten iron and slag collect in the hearth of the furnace

where they can easily be tapped off separately through openings located at different levels, since the molten iron, because of its higher specific gravity, sinks to the bottom with the slag floating on its surface.

The gaseous products of the reactions within the furnace rise through the descending column of ore, fuel, and flux, pass out through openings at the top, and are drawn through downcomers to be utilized in various ways.

CLASSIFICATION AND SOURCES OF IRON ORES.

The iron ores used in the blast-furnace industry of this country are the oxides, forming the three groups, the hematites, the brown ores, and the magnetites. An insignificent tonnage of iron-carbonate ore has been used in the past. There was no production of this ore during 1917 to 1919 and but 3,740 tons were mined in 1920.

Iron ores are also divided into the two classes, Bessemer and non-Bessemer or basic, dependent upon the content of phosphorus. This classification arises from the fact that in the acid Bessemer method of making steel no phosphorus is removed during the process. The pig iron from which the steel is made must have no greater quantity of phosphorus than will maintain the Bessemer limit of 0.1 per cent phosphorus in the steel. Since practically all the phosphorus in the ore passes into the pig iron, a Bessemer ore must not contain over 0.001 per cent phosphorus for each per cent of iron in the ore. A Bessemer ore generally contains less than 0.05 per cent phosphorus.

Ores containing more than 2 per cent manganese have been classed asmanganiferous and more than 18 per cent silica as siliceous. These are rather arbitrary classes, but are those adopted by the Lake Superior Iron Ore Association.

Approximately 85 per cent of the iron ore mined in the United States is produced in the Lake Superior region which is divided into the Mesabi, Gogebic, Menominee, Marquette, Cuyuna, and Vermilion ranges. The most important of these ranges is the Mesabi, which produces over 64.7 per cent of the iron ore from the Lake Superior areas and nearly 55 per cent of the total production of the entire country. The other ranges produce, in the order mentioned, 12.5, 10.0, 7.7, 2.6, and 2.5 per cent of the output of the Lake Superior region. The ores mined in this region are preponderantly hematites, though there is some brown ore and a little magnetite ore.

In addition to the above-mentioned ranges, a small quantity of ore comes from the Baraboo and Mayville districts in south-central and southeastern Wisconsin and from the Michipicoten range and Moose Mountain district in Ontario, Canada, which is usually grouped with the ore of the Lake Superior region.

Next in rank of production to the Lake Superior iron-ore region is the Birmingham district of Alabama. Alabama produces 9 per cent of the total production of iron ore of the United States. Of the ore mined in Alabama, 84.7 per cent is hematite, and the rest brown ore. New York State produces slightly less than 1.7 per cent of the country's total. Of this, 80 per cent is magnetite from the Adirondacks. The remaining 4.3 per cent of the iron ore mined in this

country comes from widely scattered districts in Pennsylvania, New Jersey, Wyoming, Virginia, Tennessee, New Mexico, Georgia, and other States.

BLAST-FURNACE FLUXES.

Fluxing materials are used in blast furnaces to unite with the gangue, or impurities, of the ore and the ash of the fuel so as to render them fluid at furnace temperatures. It is evident, therefore, that the nature of the flux used is determined entirely by the character of the material to be fluxed. If this is acidic it requires a basic flux; if basic, an acid flux. In this country the gangues of iron ores are in practically all cases acidic in nature and consequently require to be combined with a base to form readily fusible compounds. In a few instances, such as is the case with part of the ore mined in the Birmingham district, the gangue itself contains such proportions of bases and acids as to cause it to be self-fluxing.

The cheapest and most available basic flux is limestone. Since a cheap high-grade limestone can not be obtained in all localities, limestones containing magnesia, and even dolomites, which contain equal parts of lime and magnesia, are often used.

Pennsylvania produces about one-third of the limestone used as pig-iron flux in this country, one-fourth comes from Michigan, and about one-fifth from Ohio. In Alabama dolomite is most extensively used for fluxing purposes in pig-iron production.

BLAST-FURNACE FUELS.

Coke, coal, and charcoal are the fuels used in the blast furnace. Of these coke holds preeminently first rank. More than 98.3 per cent of the pig iron produced in this country is made with the use of coke. Charcoal is still used in a few stacks of comparatively small production for the manufacture of special irons, while the use of anthracite coal is quite rare. Where the latter is used at all it is usually mixed with coke.

Cokes are classed as beehive or by-product, dependent upon whether the bituminous coal is coked in beehive ovens or in by-product retort ovens. Beehive ovens are generally located at the bituminous coal mines, whereas by-product ovens are situated at the places of consumption. The proportion of coke produced in by-product coke ovens has increased from 27.5 per cent in 1913 to 60 per cent in 1920. The division of cokes into beehive and by-product is based entirely on the method of manufacture and does not affect their use in the blast furnace.

Pennsylvania holds first rank in the production of coke, both beehive and by-product. During the period 1913–1920 over 45.7 per cent of the country's total production was in this State. Alabama ranked second in the production of coke, with slightly over 7 per cent of the total, followed closely by Indiana and Ohio, with over 6 per cent each. West Virginia and Illinois are the next largest producers. As previously stated by-product ovens are located at the place of consumption. This usually necessitates the shipment of the coal used in the ovens from the mines. For this reason the source of most of the coal used for the coke produced in Indiana,

Illinois, and Ohio is elsewhere than in these States. Indiana and Illinois cokes are made mainly from West Virginia and Kentucky coals. Ohio imports coal from Pennsylvania, Kentucky, and West Virginia.

FACTORS GOVERNING VOLATILIZATION OF POTASH IN BLAST FURNACES.

The principal factors which influence the displacement and volatilization of potash by lime in the cement plant and blast furnace are temperature and the proportion of lime to acidic oxides (silica and alumina). The temperatures in the blast furnace are higher than in the cement kiln, but in the production of cement clinker the limestone used is such as to give an approximate ratio of lime to acids ($SiO_2 + Al_2O_3$) of 2 to 1 while in the blast furnace the ratio of bases ($CaO + MgO$) to acids for smooth running slag is approximately 1.2 to 1. The sum of the silica and alumina is usually taken as a measure of a slag's acidity. On this basis analysis shows most slags to be basic compounds having more than 50 per cent of lime and magnesia, although this is by no means always the case.

In the manufacture of ferromanganese and spiegel iron it is necessary to have a strongly basic slag to prevent loss of manganese in the slag. Such furnaces also operate at higher temperatures than those making pig iron and greater liberation of potash is therefore to be expected at furnaces making these materials.

The construction of the cement kiln offers an open unobstructed passage for the escape of the potash-bearing dust from the kilns and owing to the comparatively uniform composition of the materials entering and leaving the kilns it is possible to arrive at an approximate estimate of the potash in the dust from the analysis of a single set of samples of raw mix and ground clinker.

The conditions which prevail in the blast furnace are entirely different. The potash which is volatilized in the hottest part of the furnace has to pass up with the gases through the downcoming burden toward the upper cooler portions of the furnace where the temperature may be as low as 400° or even less. Here it is partially condensed to be carried down again to the section of the furnace where volatilization temperatures prevail. There is consequently an accumulation of potash in the furnace which, under conditions where the upper portions become hotter than usual or for other reasons, is carried over with the gases from the furnace. The dust collected in the flues of the furnace from time to time may therefore vary widely in its content of potash.

The dust collected at points most remote from the furnace contains least of the heavier particles of burden carried over mechanically by the blast and should therefore contain relatively higher percentages of potash than that collected in the downcomer and dry-dust catcher.

Analyses of flue dusts collected at various furnaces are tabulated in Table 1.

TABLE 1.—*Potash in flue dust.*

Firm.	Description.	Potash (K_2O).
		Per cent.
Adrian Furnace Co	Flue dust	0.30
Alan Wood, Iron & Steel Co	Flue dust from boilers	.23
Do	Flue dust from stoves	3.83
American Manganese Manufacturing Co	Flue dust A	9.60
Do	Flue dust B	3.88
Do	Flue dust C	4.32
Barnum Richardson Co		.95
Do		Trace.
Bass Foundry & Machine Co	Flue dust	None.
Bon Air Coal & Iron Co	do	2.06
Cambria Steel Co	Nodule flue dust	.90
Carbon Iron & Steel Co	Boiler refuse from furnace gases	8.25
Carnegie Steel Co., Isabella plant	Boiler dust from ferromanganese furnace	1.63
Charcoal Iron Co	Downcomer flue dust	1.00
Do	Boiler flue dust	2.85
Chattanooga Iron & Coal Co	Flue dust from front boilers	16.90
Do	Flue dust from back boilers	10.63
Claire Furnace Co	Boiler dust	1.74
Do	Sintered flue dust	.38
Cleveland Cliffs Iron Co	Flue dust	.41
Clinton Iron & Steel Co	Boiler dust	1.38
Colorado Fuel & Iron Co	Flue dust, basic process	1.08
Do	Flue dust, Bessemer process	.92
Cranberry Furnace Co	Dust from downcomer	.30
Do	Dust from boilers	2.04
Do	Dust from stoves	2.32
Crane Iron Works	Boiler dust	8.81
Do	Stoves	6.66
Do	Bag machine	12.12
Delaware River Steel Co	Flue dust from No. 1 boiler	3.29
Eastern Steel Co	Flue dust	.58
Ella Furnace Co	Nodulized flue dust	.41
Gulf States Steel Co	Dust from hot-blast stoves	4.32
Do	Dust from B. F. boilers	4.00
Iroquois Iron Co	Boiler flue dust	1.00
Do	Flue dust from furnace making ferromanganese	9.25
Do	Flue dust from furnace making foundry iron	.37
Do	Flue dust from furnace making malleable iron	.27
Do	Flue dust from furnace making bessemer iron	.21
Jones & Laughlin Steel Co	Boiler dust from Eliza furnaces	2.85
Do	Scrapings from stove chimney	1.22
Do	Flue dust, No. 3 dust catcher	.22
Do	Flue dust, boilers	.24
Do	Flue dust, separator	.34
McKeefrey Iron Co	Flue dust	2.60
Mississippi Valley Iron Co	do	.30
Natonal Tube Co	Dust from stoves	4.67
Do	Dust from blast furnaces	1.23
Do	Dust from combustion chamber in stoves	3.70
Do	Soft deposit at bottom of boiler stacks	3.57
Do	Hard deposit from boilers	.17
Do	Flue dust	.26
Northwestern Iron Co	Flue dust, A and B furnaces	.95
Do	Boiler dust	3.64
Do	Sinter made from flue dust	.55
Do	Flue dust from A furnace boilers	2.46
Do	Flue dust from B furnace boilers	2.27
Pittsburgh Steel Co	Sinter	.53
Princess Furnace Co	Flue dust from No. 5 and No. 6 boilers	5.62
Reading Iron Co	Downcomer	.30
Do	Flue dust from stoves	5.93
Robesonia Iron Co	Flue dust	19.75
Shenango Furnace Co	Flue dust from No. 3 furnace dust legs	Trace.
Do	Flue dust from No. 1 furnace and old gas washer	.29
Sligo Furnace Co	Dust from No. 2 boiler	1.01
Struthers Furnace Co	Sintered flue dust	.65
Toledo Furnace Co	Flue dust from A furnace	.42
Do	Flue dust from B furnace	.62
Do	Flue dust	1.68
United Iron & Steel Co	Flue dust from dust catcher	.29
Warner Iron Co	Blast-furnace dust from Cumberland furnace	3.96
Wisconsin Steel Co	Flue dust from boilers 5, 6, 7, and 8	None.
Worth Bros. Co	Flue dust from No. 6 boiler	9.57
Do	Flue dust from No. 7 boiler	7.61
Do	Stove cinder	1.74
Do	Flue dust	1.37
Youngstown Sheet & Tube Co	Flue dust, No. 1 furnace	.41
Do	Flue dust, No. 2 furnace	.34
Do	Blast furnace dust	.41

POTASH IN BLAST-FURNACE RAW MATERIALS AND SLAGS.

The systematic collection of the iron ore, fuel, and flux samples was made through the cooperation of Frederick Crabtree, of the Bureau of Mines. Each sample was analyzed for potash by at least two chemists with the results given in Tables 2 to 10.

The figures for ore production in column 3 of Table 2 were derived from statistics of the Lake Superior Iron Ore Association and used for obtaining weighted averages. Those of Tables 4, 5, and 7 are the average annual productions or importations for the years 1913 to 1920 obtained from statistics of the United States Geological Survey.[5]

The potash content of the ores is shown to range from a minimum of 0.04 per cent for some Lake Superior ores to over 2 per cent for certain foreign manganese ores. Samples from the Menominee and Marquette ranges contained between two and three times as much potash as those from the Mesabi Range. The potash content in the ores from the same range agreed so closely that no material difference was found between the mean and weighted averages for any range. This close agreement prevailed both for Bessemer and non-Bessemer ores.

Southern iron ores and manganese ores are usually richer in potash than the Lake Superior ores.

Mention may be made of the gray hematites of eastern and northeastern Alabama, large workable ore bodies of which exist in Talladega County. These ores have been used for considerable periods of time at three furnaces—Gadsden, Ironaton, and Shelby. Four samples of these ores were found to contain 1.79, 1.87, 1.91, and 2.66 per cent K_2O, respectively. The first of these samples was obtained from the Shelby Iron Ore Co. and the other three forwarded by E. F. Burchard, of the United States Geological Survey. The analyses of slags are given in Table 11.

TABLE 2.—*Potash in ores of the major Lake Superior ranges.*

MESABI RANGE.

Ore.	Kind.	Annual production.	Potash (K_2O).
		Gross tons.	*Per cent.*
Adriatic	Non-Bessemer	57,000	0.12
Albany	do	157,000	.07
Bangor	do	55,000	.11
Beaver	do	992,000	.09
Bennett	do	123,000	.10
Bruce	do	87,000	.12
Brunt	do	43,000	.07
Commodore	do	208,000	.07
Corsica non-Bessemer	do	74,000	.08
Danube	do	28,000	.10
Dover	do	27,000	.13
Grade X	do	95,000	.07
Grant	do	28,000	.07
Group 3	do	6,109,000	.11
Group 4	do	1,500,000	.09
Group 6	do	93,000	.06
Group 7	do	2,249,000	.05
Group 9	do	1,029,000	.12
Harold	do	21,000	.08
Helmer	do	156,000	.09
Hudson No. 2	do	4,000	.09
Jerome	do	16,000	.07

[5] Burchard, E. F., et al. Mineral Resources of the United States. United States Geological Survey, Dept. of the Interior, 1913–1920.

TABLE 2.—*Potash in ores of the major Lake Superior ranges*—Continued.

MESABI RANGE—Continued.

Ore.	Kind.	Annual production.	Potash (K_2O)
		Gross tons.	*Per cent.*
Kevin	Non-Bessemer	38,000	0.10
Kinney	do	47,000	.08
Kipp	do	28,000	.06
Knox	do	24,000	.24
Lambert	do	292,000	.11
Leetonia	do	93,000	.04
Leonard	do	116,000	.09
Mohawk	do	64,000	.10
Nashwauk	do	19,000	.12
North Harrison	do	39,000	.08
Perkins	do	25,000	.06
Risco	do	54,000	.07
St. James	do	247,000	.12
Shilling	do	343,000	.13
Stanton	do	7,000	.08
Wilpen	do	383,000	.07
Woodbridge	do	173,000	.12
Athens	Bessemer	6,000	.08
Belgrade	do	45,000	.11
Biwabik	do	16,000	.09
Cooley	do	43,000	.07
Corsica Bessemer	do	22,060	.08
Crete	do	43,000	.10
Crosby	do	108,000	.10
Crown	do	102,000	.10
Dale Uno	do	10,000	.15
Douglas	do	89,000	.08
Elba	do	51,000	.09
Gilwood	do	43,000	.08
Grade B	do	156,000	.15
Group 1	do	1,752,000	.07
Group 2	do	4,659,000	.06
Group 5	do	1,212,000	.06
Group 10	do	195,000	.12
La Rue	do	23,000	.11
Mace	do	352,000	.10
Mahoning	do	383,000	.06
Malta	do	9,000	.10
Meriden	do	110,000	.10
Ruddy	do	8,000	.12
Smith	do	102,000	.12
Stevenson	do	42,000	.09
Albany Rex	Manganiferous	37,000	.10
Bennett Rex	do	28,000	.07
Meadow	do	76,000	.12

GOGEBIC RANGE.

Andrews	Non-Bessemer	600,000	0.10
Colby No. 2	do	118,000	.14
Eureka	do	193,000	.14
Glyuna	do	98,000	.17
Hamilton	do	140,000	.05
Mikado	do	8,000	.12
Montrose	do	274,000	.10
Norman	do	305,000	.12
Palms Tower	do	117,000	.07
Plymouth	do	459,000	.07
Walton	do	4,000	.10
Ashland	Bessemer	9,000	.07
Aurora	do	24,000	.05
Brotherton No. 2	do	44,000	.09
Cary Bessemer	do	28,000	.10
Lawrence	do	26,000	.08
Melrose	do	448,000	.07
Melrose special	do	148,000	.08
Nordale	do	618,000	.06
Norrie	do	664,000	.07
Royal	do	6,000	.06
Sunday Lake	do	107,000	.06
Cary Empire	Manganiferous	92,000	.12
Ontario	do	158,000	.11

TABLE 2.—*Potash in ores of the major Lake Superior ranges*—Continued.

MENOMINEE RANGE.

Ore.	Kind.	Annual production.	Potash (K_2O).
		Gross tons.	*Per cent.*
Balkan	Non-Bessemer	69,000	0.13
Baltic	do	217,000	.34
Bates	do	81,000	.12
Brule	do	6,000	.22
Buckeye	do	12,000	.10
Cadiz Townsite	do	32,000	.11
Carpenter	do	301,000	.16
Cedar	do	86,000	.68
Dunn	do	3,000	.12
Forbes	do	35,000	.24
Harper	do	113,000	.12
Homer	do	161,000	.44
James	do	70,000	.22
Judson	do	92,000	.33
Michigan	do	4,000	.31
Odgers	do	61,000	.19
Ravenna	do	6,000	.34
Richards	do	2,000	.24
Russell	do	112,000	.29
Tobin	do	220,000	.24
Tully	do	70,000	.19
Cyclops	Bessemer	11,000	.29
Vulcan	do	107,000	.13
Clifford	Siliceous	65,000	.47
Pewabic Genoa	do	72,000	.13
Manganate	Manganiferous	204,000	.28
Mango	do	2,000	.27

MARQUETTE RANGE.

Abbotsford	Non-Bessemer	22,000	0.21
Ambos	do	11,000	.48
Cambria	do	71,000	.22
Cambridge	do	224,000	.17
Castleford	do	50,000	.34
Cliffs Shaft	do	252,000	.40
Imperial	do	10,000	.09
Maas	do	95,000	.20
Negaunee non-Bessemer	do	414,000	.24
Republic basic crushed	do	56,000	.30
Rolling Mill	do	47,000	.06
Washington No. 2	do	1,000	.17
American crushed	Bessemer	83,000	.37
Lake Angeline	do	18,000	.04
Lake Bessemer	do	318,000	.18
Negaunee	do	33,000	.17
Palmer	do	8,000	.29
Empire	Siliceous	19,000	.05
Iron Mountain	do	1,000	.06
Richmond	do	137,000	.18

CUYUNA RANGE.

Armour No. 1	Non-Bessemer	51,000	0.10
Kennedy	do	145,000	.09
Mahnomen	do	40,000	.12
Pennington	do	126,000	.05
Croft	Bessemer	65,000	.09
Mahnomen No. 1	Manganiferous	27,000	.26
Mangan No. 1	do	16,000	.25
Sultana	do	22,000	.30

VERMILION RANGE.

Chandler	Bessemer	40,000	0.10
Pattison	do	34,000	.13
Savoy	do	172,000	.08
Section 30	Non-Bessemer	80,000	.11

TABLE 3.—*Potash in ores of minor Lake Superior ranges.*

Ore.	Range.	Kind.	Annual production, estimated.	Potash (K_2O).
			Gross tons.	*Per cent.*
Cahoon	Baraboo	Non-Bessemer	50,000	0.49
Mayville	Mayville	do	85,000	.39
Magpie	Michipicoten	Bessemer	150,000	.14
Moose Mountain	Moose Mountain	do	25,000	.13

TABLE 4.—*Potash in American ores other than those from the Lake Superior region.*

Source.	Mine.	Variety.	Annual production of State.	Potash (K_2O).
			Gross tons.	*Per cent.*
Alabama	Greeley	Brown ore	5,731,000	0.32
Do	Russellville	do		.25
Do	Ishkooda	Hematite		.17
Do	Muscoda	do		.37
Do	Raimund	Hematite (soft ore)		.50
Do	do	Hematite (hard ore)		.73
Do	Spaulding	Hematite		.80
Do		Brown ore		.49
Do		Hematite		.60
Georgia	Estelle	Hematite (soft ore)	158,000	1.00
Do	do	Hematite (hard ore)		.52
Do	Cedartown	Brown ore		.93
Missouri	Puxico	Hematite	47,000	.28
New Jersey	Mount Hope	Magnetite	417,000	.27
Do	Washington	do		.14
New Mexico	Corona	Hematite	160,000	.11
Do	Jim Fair	Magnetite		.07
Do	Oro Grande	Hematite		.09
Do	Snowflake	Magnetite		.16
Do	Union Hill	do		.09
New York	Forest of Dean	do	1,073,000	.12
Do	Harmony concentrates Port Henry.	do		.10
Do	Old bed concentrates Port Henry.	do		.08
North Carolina	Cranberry	do	73,000	.21
Pennsylvania	Cornwall	do	531,000	.39
Virginia	Fenwick	Brown ore	395,000	.17
Do	Jordon	do		.30
Do	Longdale	do		.46
Do	Oriskany	do		.08
Do	Rich Patch	do		.34
Wyoming	Sunrise	Hematite	460,000	.98

TABLE 5.—*Potash in domestic manganese ores.*

Source.	Annual production.	Potash (K_2O).	Source.	Annual production.	Potash (K_2O).
	Gross tons.	*Per cent.*		*Gross tons.*	*Per cent.*
Arizona	9,000	0.21	Georgia (Cartersville)	3,000	.86
Colorado (Leadville)	5,000	.43	Montana (Phillipsburg)	90,000	1.45

TABLE 6.—*Potash in foreign manganese ores.*

Source.	Number of samples analyzed.	Potash (K_2O).	Source.	Number of samples analyzed.	Potash (K_2O).
		Per cent.			*Per cent.*
Africa (Wasson)	1	1.26	China	1	1.14
Brazil	1	.29	Cuba	2	.84
Do	3	.56	Do	1	1.15
Do	4	.78	India	2	.40
Do	1	.96	Do	2	.75
Do	2	1.52	Do	1	2.37
Chile	2	.08	Porto Rico	1	.16
China	1	.66			

TABLE 7.—*Potash in foreign iron ores.*

Source.	Annual importation.	Samples analyzed.	Potash (K_2O).
	Gross tons.		*Per cent.*
Canada	101,000	3	0.14
Sweden	155,000	2	.15

TABLE 8.—*Average potash content in ores from various sources.*

Source of ore.	Annual production or importation.	Ores analyzed.	Total samples analyzed.	Potash (K_2O), weighted average.
	Gross tons.			*Per cent.*
Mesabi Range	34,800,000	67	115	0.09
Gogebic Range	6,679,000	24	44	.09
Menominee Range	5,363,000	27	38	.26
Marquette Range	4,139,000	20	28	.24
Cuyuna Range	1,416,000	8	8	.11
Vermilion Range	1,365,000	4	8	.09
Alabama	5,731,000	9	9	.44
New York	1,073,000	3	3	.10
Pennsylvania	531,000	1	1	.39
Wyoming	460,000	1	1	.98
New Jersey	417,000	2	2	.21
Virginia	395,000	5	5	.27
New Mexico	160,000	5	5	.10
Georgia	158,000	3	3	.82
Miscellaneous domestic	767,000	2	7	.25
Domestic manganese	79,000	4	4	1.28
Foreign manganese	447,000	15	25	.85
Foreign nonmanganiferous	1,012,000	2	5	.15
Weighted average for all ores				.17

TABLE 9.—*Potash in fuels.*

Source.	Kind.	Ash.	Potash (K_2O) in the fuel.	Source.	Kind.	Ash.	Potash (K_2O) in the fuel.
		Per ct.	*Per ct.*			*Per ct.*	*Per ct.*
Pennsylvania	B. H. Coke	12.01	0.14	Pennsylvania	B. H. Coke	9.48	0.13
Do	do	9.69	.13	Do	do	9.99	.16
Do	do	11.13	.10	Do	do	10.85	.17
Do	do	12.13	.16	Do	do	11.78	.22
Do	do		.12	Do	do	12.67	.20
Do	do	16.03	.15	Do	do		.17
Do	do	13.19	.17	Do	do		.26
Do	do	11.48	.14	Do	do		.15
Do	do	9.85	.16	Do	do		.18
Do	do	10.25	.16	Do	do		.21
Do	do	9.74	.15	Do	do		.17
Do	do	10.00	.15	Do	do	12.31	.15
Do	do	10.62	.17	Do	do	13.05	.17
Do	do	10.00	.15	West Virginia	do	8.12	.24
Do	do	11.25	.18	Do	do	11.00	.12
Do	do	12.21	.21	Do	do	13.15	.25
Do	do	10.36	.17	Do	do	10.85	.19
Do	do	10.69	.17	Do	do	10.52	.18
Do	do	9.68	.15	Do	do	12.19	.20
Do	do	9.81	.16	Do	do	6.67	.06
Do	do	10.96	.16	Do	do	7.89	.06
Do	do	9.83	.18	Do	do		.17
Do	do	10.27	.15	Alabama	do		.27
Do	do	11.05	.16	Do	do		.16
Do	do	10.19	.15	Do	do		.34
Do	do	10.65	.16	Colorado	do		.09
Do	do	10.70	.15	Do	do		.05
Do	do	12.56	.19	Do	do		.04
Do	do	10.75	.16	Do	do		.09

TABLE 9.—*Potash in fuels*—Continued.

Source.	Kind.	Ash.	Potash (K_2O) in the fuel.
		Per ct.	*Per ct.*
Kentucky	B. H. Coke.	5.79	0.13
Virginia	do	9.39	.33
Tennessee	do	18.52	.37
Do	do	18.29	.34
Location of oven:			
Pennsylvania	B. P. Coke.		.20
Do	do		.19
Do	do	13.43	.20
Do	do		.19
New York	do		.22
Do	do	9.74	.15
West Virginia	do		.15
Ohio	do		.11
Do	do	10.15	.23
Do	do	12.08	.20
Do	do	12.18	.35
Location of oven—Continued.			
Ohio	B. P. Coke.		0.17
Do	do		.20
Do	do		.25
Do	do		.26
Wisconsin	do	11.08	.28
Michigan	do	11.78	.18
Indiana	do		.30
Illinois	do		.23
Pennsylvania	Coal	10.78	.16
Ohio	do		.16
Wisconsin	Charcoal		.25
Do	do		.46
Average for all fuels			.18

TABLE 10.—*Potash in fluxes.*

Source.	Potash.
Limestones:	
Pennsylvania—	*Per cent.*
Blair County	0.32
Do	.52
Do	.14
Do	.18
Do	.45
Do	.18
Do	.26
Do	.12
Center County	.14
Dauphin County	.12
Lawrence County	.19
Do	.21
Lebanon County	.11
Mifflin County	.19
Do	.49
Berks County	.09
Cumberland County	.21
Montgomery County	.26
Ohio—	
Erie County	.05
Do	.05
Do	.06
Franklin County	.07
Mahoning County	.18
Do	.23
Do	.18
Miami County	.09
Ottawa County	.18
Do	.05
Do	.05
Trumbull County	.31
Do	.49
Lucas County	.14
Do	.23
Sandusky County	.19
Do	.26
Erie County	.05
Seneca County	.05
Limestones—Continued.	
Ohio—	*Per cent.*
Wyandot County	0.05
Michigan—	
Emmet County	.22
Do	.08
Schoolcraft County	.06
Wayne County	.07
Arenac County	.04
West Virginia—	
Berkeley County	.26
Jefferson County	.10
Tennessee—	
Carter County	.47
Hamilton County	.06
Colorado, Fremont County	.03
Missouri, Pike County	.17
New York—	
Niagara County	.11
Do	.19
Virginia, Allegheny County	.08
Wisconsin—	
Dodge County	.04
Do	.06
Dolomites:	
Alabama—	
Jefferson County	.03
Do	.07
Do	.10
Ohio—	
Seneca County	.04
Do	.03
Do	.03
Do	.03
Wisconsin, Dodge County	.13
Average for all fluxes	.16

TABLE 11.—*Potash in slag.*

Firm.	Location of furnace.	Potash (K_2O) in slag.	Furnace.
		Per cent.	
Antrim Iron Co.	Mancelona, Mich.	2.26	
Bethlehem Steel Co.	Cornwall, Pa.	1.02	North Cornwall.
Brier Hill Steel Co.	Youngstown, Ohio.	.57	Tod.
Do.	do.	.51	Grace.
Cambria Steel Co.	Johnstown, Pa.	.55	
Charcoal Iron Co.	Manistique, Mich.	.54	Manistique.
Chattanooga Iron & Coal Corporation.	Chattanooga, Tenn.	.74	
Claire Furnace Co.	Sharpsville, Pa.	.46	
Cleveland Furnace Co.	Cleveland, Ohio.	.48	
Colorado Fuel & Iron Co.	Pueblo, Colo.	.43	
Columbus Iron & Steel Co.	Columbus, Ohio.	.29	East.
Do.	do.	.29	West.
The Cranberry Furnace Co.	Johnson City, Tenn.	.86	
Empire Steel & Iron Co.	Oxford, N. J.	.97	
Iroquois Iron Co.	South Chicago, Ill.	.08	No. 1 (on ferromanganese).
Do.	do.	.56	No. 2 (on foundry iron).
Do.	do.	.53	No. 3 (on malleable iron).
Do.	do.	.47	No. 4 (on Bessemer iron).
Jackson Iron & Steel Co.	Jackson, Ohio.	.43	
Jones & Laughlin Steel Co.	Pittsburgh, Pa.	.45	
Lackawanna Steel Co.	Lackawanna, N. Y.	1.19	No. 1.
Do.	do.	1.01	No. 4.
Do.	do.	.56	No. 5.
The Low Moor Iron Co.	Lowmoor, Va.	.52	
Mississippi Valley Iron Co.	St. Louis, Mo.	.88	
National Tube Co.	McKeesport, Pa.	.60	
Do.	Lorain, Ohio.	.49	No. 1.
Do.	do.	.34	No. 2.
Do.	do.	.44	No. 3.
Do.	do.	.41	No. 4.
Do.	do.	.32	No. 5.
Do.	Benwood, W. Va.	.59	
Northwestern Iron Co.	Mayville, Wis.	1.01	
Ohio Iron & Steel Co.	Lowellville, Ohio.	.74	
Perry Iron Co.	Erie, Pa.	.54	
Pittsburgh Steel Co.	Monessen, Pa.	.65	No. 2.
Reading Iron Co.	Reading, Pa.	.37	
Republic Iron & Steel Co.	Youngstown, Ohio.	.40	Haselton No. 1.
Do.	do.	.31	Haselton No. 2.
Do.	do.	.29	Haselton No. 3.
Do.	do.	.34	Haselton No. 4.
Do.	New Castle, Pa.	.72	Atlantic.
Do.	Youngstown, Ohio.	.52	Hannah.
Do.	Sharon, Pa.	.17	Hall.
Do.	Thomas, Ala.	1.17	
River Furance Co.	Cleveland, Ohio.	.32	A.
Do.	do.	.40	A.
Do.	do.	.20	B.
Do.	do.	.21	B.
Struthers Furnace Co.	Struthers, Ohio.	.57	
Tennessee Coal, Iron & Railroad Co.	Ensley, Ala.	.99	
Toledo Furnace Co.	Toledo, Ohio.	.56	A.
Do.	do.	.65	B.
United Furnace Co.	Canton, Ohio.	.60	
United Iron & Steel Co.	Leetonia, Ohio.	.53	
Wickwire Steel Co.	Buffalo, N. Y.	.59	X.
Do.	do.	.35	Y.
Witherbee, Sherman Co.	Port Henry, N. Y.	.38	
Worth Bros.	Coatesville, Pa.	.34	
Youngstown Sheet & Tube Co.	Youngstown, Ohio.	1.00	A.
Do.	do.	.73	B.
Do.	do.	.47	C.
Do.	do.	1.36	D.
Do.	do.	.98	No. 1.
Do.	do.	.38	No. 2.
Average for all slags.		.59	

ESTIMATED LOSS OF POTASH IN THE BLAST-FURNACE INDUSTRY.

Tables 8, 9, and 10 show that the potash content of the numerous samples of ore, coke, and limestone that were analyzed give an average about the same for each material of approximately 0.2 per cent. The average percentage of potash in the raw mix used in cement manufacture (0.67 per cent) is therefore over three times as great as that occurring in the raw materials consumed in the blast-furnace industry.

TABLE 12.—*Estimated loss of potash in blast-furnace industry.*

Material.	Annual consumption.[1]	Average potash (K_2O) content.	Total potash (K_2O) content.	Potash (K_2O) per gross ton of pig iron.
	Short tons.	*Per cent.*	*Short tons.*	*Pounds.*
Ore	72,800,000	0.17	123,800	7.3
Limestone	18,400,000	.16	29,400	1.7
Coke	38,700,000	.18	69,700	4.1
Total in charge			222,900	13.1

Material.	Production.	Average potash (K_2O) content.	Total potash (K_2O) content.	Potash (K_2O) per gross ton of pig iron.
		Per cent.	*Short tons.*	*Pounds.*
Pig iron, gross tons	33,700,000			
Slag, short tons	23,600,000	0.59	139,200	8.2
Total lost by volatilization			83,700	4.9

[1] The figures for consumption and production of ore, limestone, coke, and pig iron are average values obtained from Annual Statistical Reports, American Iron and Steel Institute 1913 to 1920. The production of slag was calculated from the ratios of slag to pig iron for numerous blast furnaces throughout the country.

In an investigation that was made some time ago by R. J. Wysor [6] of the Bethlehem Steel Co., it was reported that the potash in the ore, coke, and limestone used at that plant amounted, respectively, to 10.3, 5.8, and 6.3 pounds per ton of pig iron, or to a total of 22.4 pounds per ton.

The results given in Table 12, which represent an average as applied to all the blast furnaces of the country, show corresponding values of 7.3, 4.1, and 1.7 pounds per ton of pig iron or a total of 13.1 pounds. The average potash in the slags, on the other hand, was found to be almost twice as great as reported by Wysor for the Bethlehem Steel Co. It therefore follows, as Wysor himself predicted, that the potash volatilized per ton of pig iron must be less for the average plant than was found for the Bethlehem plant. According to our results this amounts to only 4.9 pounds per ton of iron as compared with Wysor's 17.9 pounds.

That the potash lost at the Bethlehem plant is about three times greater than the average for the blast furnaces of the country as a whole is further indicated by the potash found in the dust collected

[6] Wysor, R. J. Potash as a By-Product from the Blast Furnace. Bul. Am. Inst. Mining Eng. No. 121, pp. 1–32, 1917.

in the stoves and boilers of different plants. The average given by Wysor for dusts collected at the Bethlehem plant amounted to 9.9 per cent. The average value which we have found for the potash in 78 samples of dust collected at various other plants amounts to only 2.9 per cent, or less than one-third of that for the Bethlehem plant.

If our value of 4.9 pounds be taken as to the average quantity of potash volatilized per ton of pig iron and an average normal production of iron of 33,700,000 gross tons be assumed, then the total potash volatilized from the blast furnaces of this country will amount to about 84,000 tons, as compared with the 87,000 tons found for cement plants. As there are twice as many blast-furnace plants as cement plants in the United States, the quantity of potash lost per individual plant must therefore be less in the blast-furnace industry than in the cement industry.

POSSIBILITY OF POTASH RECOVERY.

When the survey was made of the cement industry it was recognized that the dust from some plants was probably too low grade ever to be used as a source of potash, even if no cost were involved in collecting the dust. The richness of the dust in other plants indicated, on the other hand, that potash could be profitably recovered from this source, particularly if some inexpensive means were installed along the lines of the process developed at the Santa Cruz plant, whereby a mechanical separation of the potash and the dust is brought about during the process of collecting.

The blast furnace, in addition to reducing iron ore to metallic iron, is also a gas producer. The gases that issue from the top of the furnace are inflammable and have a heat value of from 90 to 100 British thermal units per cubic foot at standard conditions of temperature and pressure. It is therefore customary, in order to effect economies in the operation of the plant, to utilize this gas. It is, however, contaminated by dust which makes burning at maximum efficiency difficult. The impurities absorb heat and are also deposited in the combustion chambers of the stoves and on the tubes of the boilers, where they restrict the absorption of heat. They also combine with the brickwork of the stoves, forming fusible compounds which result in more rapid deterioration of the bricks.

The problem, consequently, is presented to the operator of cleaning his gases before their utilization. Most blast furnaces of the country are equipped with some kind of cleaner. Many of the furnaces have a dry-dust catcher, which is a large vertical steel chamber with a conical top and bottom and cylindrical center with a diameter from 15 to 30 feet. The principle of the operation of the dust catcher is merely that of the decreased velocity due to increase of area of the conducting pipe, allowing the dust to settle. The accumulated dust is discharged through an opening at the bottom of the inverted conical bottom. The best dust catchers remove about 50 per cent of the total amount of dust carried in the gas. This dust is high in iron and coke content and contains comparatively little potash, that present being largely in the insoluble state.

The dust not retained in the dry-dust catcher is for the most part exceedingly fine in character, the coarser particles having been removed in the catcher. The gases containing this fine material are

frequently led directly to the stoves and boilers without further treatment. For further purification of the gases, the practice in the United States has been to use washing systems. As a result, the greater part of the volatilized potash is now lost in these washers. The possible recovery of potash in this industry is therefore dependent on the substitution of a dry system of purifying the gases for the present wet systems. Among the dry systems for cleaning gases which give promise of successful application for potash recovery may be mentioned the Halberg-Beth, the Cottrell, and the Kling-Weidlein. The Halberg-Beth system is based primarily on the filtering of the gases through canvas bags, the Kling-Weidlein system filters the gases through steel wool, and the Cottrell process removes the solid particles by electrical precipitation. In the British Isles a modification of the Cottrell precipitator known as the Lodge electrostatic system has been used.

In the Halberg-Beth system the gases must first be cooled to about 80° C. If the temperature much exceeds this there is danger of the bags scorching, and at lower temperatures proper filtration is prevented by the condensation of water vapor on the bags, which are likely to be torn by the damp mass of accumulated dust adhering to them. After leaving the canvas bags the gas needs no further cleaning for use in gas engines.

The Kling-Weidlein system requires no preliminary cooling of the gases. It is claimed to have given satisfactory results at the Ohio works of the Carnegie Steel Co., Youngstown, and at the plant of the Ford Motor Co., at Detroit.

The Cottrell process makes use of an intermittent direct current of high tension, which imparts a charge to the suspended particles of dust, which are, under the influence of the strong electric field, driven forcibly against surrounding objects. No previous cooling of the gases is necessary. The Cottrell system has found very successful application in the recovery of potash in the cement industry, and, as applied to the blast-furnace industry, has been running successfully for approximately four years at Dunbar, Pa., on pig iron, speigeleisen, and ferromanganese, and for three years at Sheridan, Pa., on pig iron and ferromanganese.

In Table 13 is given a list of blast furnaces in this country and in the British Isles where dry cleaners have been installed and the systems used.

TABLE 13.—*Blast furnaces fitted with dry cleaning plants.*

GREAT BRITAIN.

	Type of plant.
Appleby Iron & Steel Co	Halberg-Beth.
Baldwins Ltd. Port Talbot	Do.
Barrow Steel & Iron Co. (Ltd.)	Do.
Blaenavon Coal & Iron Co. (Ltd.)	Do.
Ebb Vale Steel & Iron Co	Do.
North Lincolnshire Iron Co	Do.
Millom & Askam Iron Co	Do.
Palmers Shipbuilding & Iron Co	Do.
Shelton Iron Co	Kling-Weidlein.
Skinningrove Iron Co	Lodge electrostatic.
Workington Iron Co	Experimental electrostatic.

TABLE 13.—*Blast furnaces fitted with dry cleaning plants*—Continued.

UNITED STATES.

	Type of plant.
American Manganese Manufacturing Co., Dunbar, Pa	Cottrell.
Bethlehem Steel Co., South Bethlehem, Pa	Do.
Brier Hill Steel Co., Youngstown, Ohio	Kling-Weidlein.
Cambria Steel Co., Johnstown, Pa	Do.
Carnegie Steel Co. (Ohio works), Youngstown, Ohio	Do.
Carnegie Steel Co. (New Castle works), New Castle, Pa	Do.
Colorado Fuel & Iron Co., Pueblo, Colo	Cottrell.
Crane Iron Works, Catasaqua, Pa	Bag filter.
The Ford Co. (Inc.), Dearborn, Mich	Kling-Weidlein.
Lavino Furnace Co., Sheridan, Pa	Cottrell.
Edward E. Marshall, Harrisburg, Pa	Do.
Tennessee Coal, Iron & Railroad Co., Birmingham, Ala	Kling-Weidlein.

Owing to the low potash content of the materials used in some plants, it will no doubt be found that the dust from these plants, if collected, will be too low grade to be used as a source of potash, unless it is found to contain other products of value which will contribute to the cost of concentrating potash. It is also certain that the cost of installation excludes the possibility of recovery at most small furnaces. The situation with respect to plants operating on manganiferous, manganese, southern, or Marquette and Menominee ores should be entirely different. Owing to the relatively high potash content of these ores, it is possible that the dust from these plants will be found to be richer than the richest cement dust.

It has been shown that the amount of potash volatilized in cement kilns may be considerably increased by such chemical means as the addition of ordinary salt to the raw mix or to the coal used for fuel. Similar results have been obtained in experiments at blast furnaces in the British Isles, in which it was found that the addition of salt to the charge doubles or even quadruples the quantity of potash in the gas.[7]

It may finally be emphasized that if dry systems eventually find general use for purifying blast furnace gases the collected dust, although possibly not extensively used as a source of potash under normal conditions may nevertheless serve as an important potential source of potash which would be immediately available in case of future emergency.

SUMMARY.

The weighted average of the potash in the ores, coke, and limestone used in the blast-furnace industry amounts to approximately 0.2 per cent for each material, which is less than one-third as great as that found for the raw mix used in the cement industry. In the case of the ores, the potash ranges from 0.04 per cent for Mesaba ores to over 2 per cent for certain foreign ores. As the consumption of high-potash ores is relatively small as compared with low-potash ores, the weighted average of the potash in the ores consumed is less than the mean average found for different ore samples. The total potash in the ore, coke, and limestone used in blast furnaces amounts, respectively, to 7.3, 4.1, and 1.7 pounds per ton of pig iron, or to a

[7] Chance, Kenneth M. The Prospects of Founding a Potash Industry in this Country. J. Soc. Chem. Ind. v. 37, p. 222-230 T. 1918.

total of 13.1 pounds. The potash in the slag amounts to 8.2 pounds, which leaves a balance for the potash volatilized of 4.9 pounds per ton of pig iron. This amounts to a total for all plants of about 84,000 tons annually, as compared with 87,000 tons for the cement industry. As there are twice as many blast furnaces as cement plants in the United States, the quantity of potash lost per individual plant must therefore be less in the blast-furnace industry than in the cement industry, but it is possible that the dust from some blast furnaces in which manganiferous or southern ores are used may be richer than the richest cement dust.

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22

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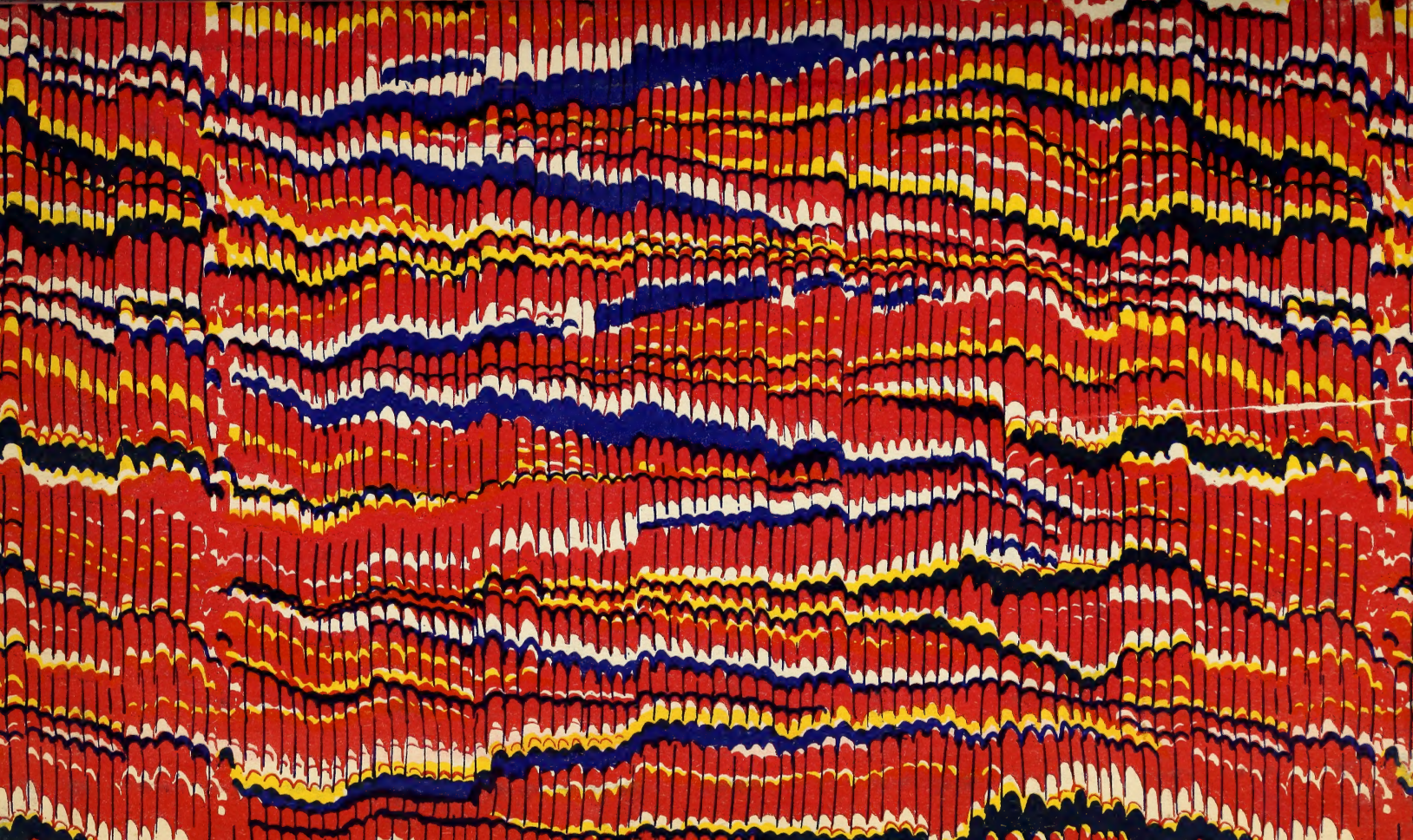

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